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Effects of 50:50 proportion Bull:Cow Blend Levels and Incorporation of Finely Textured Beef on the Color of Precooked Ground Beef Patties

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Effects of 50:50 proportion Bull:Cow Blend Levels and Incorporation of Finely Textured Beef on the Color of Precooked Ground Beef Patties

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by

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Abstract

Variation in internal cooked color of ground beef is an economic concern for the ground beef market. Persistent pink color in hamburger patties can lead consumers to the perception of an undercooked product. Therefore, the objective of this study was to characterize the effects of bull:cow blend proportions, with or without finely textured beef (FTB), and cookery method on internal color of precooked ground beef patties. Batches (9.1 kg) of 85% lean ground beef were manufactured with 0, 33, 67, or 100% 50:50 bull:cow blend (remainder of lean was 100, 67, 33, or 0% Select-grade knuckles, respectively) mixed with 2 kg of 50:50 lean:fat trim and either 0 or 15% FTB, resulting in 8 treatment formulations with 5 replicates. Batches were mixed in a commercial mixer-grinder for 5 min before being ground through a 0.95-cm plate, and formed into 150-g patties (40/batch). Fresh color (L*, a*, and b*) was measured after patties were formed (n=6/ treatment batch). Patties were cooked in an impingement oven to internal temperature of 71°C, submerged in an ice bath before measuring internal cooked color (n=6). The next day, frozen cooked patties were reheated to an internal endpoint temperature of 71°C on a char-grill (CHAR), clam-shell griddle (PAN), or forced-air convection oven (OVEN) before measuring internal reheated color. Data were analyzed as a slit-plot design, with the whole plot treatments in a 4 × 2 factorial arrangement with PROC GLIMMIX of SAS. Fresh patties became darker, less red, and more yellow (linear, $P \leq 0.012$) with increasing proportions of bull:cow blend, whereas FTB addition increased ($P < 0.05$) L* values and decreased ($P < 0.05$) a* and b* values of fresh patties. Cooked patties became darker (linear, $P < 0.001$) with increasing bull:cow blend, and addition of FTB reduced ($P < 0.05$) internal a* and b*. Reheated L* values decreased with increasing bull:cow blend (linear, $P < 0.001$), and inclusion of FTB reduced (P <

0.05) a^* values in reheated patties. Patties reheated in OVEN were lighter ($P<0.05$), more red ($P < 0.05$), and yellow ($P < 0.05$) than patties reheated in PAN or on CHAR.

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Chapter I: Review of Literature

Introduction

Ground beef patties can be one of the most problematic products to cook. Problems associated with color variability in ground beef hamburger patties cooked to specific internal temperatures, especially 71°C, have increased concerns for ground beef processors, regulatory agencies, foodservice operations and consumers. The message from the USDA since 1998 for consumers is to use a meat thermometer when cooking ground beef patties, because cooked color is not a reliable indicator that the patties reached a temperature high enough to destroy bacterial pathogens, e.g. *E. coli* O157:H7. Some consumers associate "pink" color in cooked meat as raw product. There are many known factors that cause this persistent pinkness such as high muscle pH from dark cutters and bull meat used in the ground meat formulation (Moiseev and Cornfort, 1999). Therefore, the objective of this literature review is to examine ground beef patty production and usage, the causes of persistent pinkness, and the use of lean finely textured beef in burger patties.

Beef Patty Usage

Ground beef comprises between 50 and 60% of the beef consumed in the United States (Laird et al., 2019). Ground beef is a popular meat purchase, for it is one of the least expensive beef products available to consumers (Speer et al. 2015). Ground beef can be manufactured from a wide variety of raw materials, can possess different percentages of fat, and can be sold in various product forms. Given that ground beef is one of the most affordable beef products sold in the United States and represents the largest volume of beef sold in the food service industry (64%), and represents more than 37% of revenue sales for both food service and retail industries, respectively (Speer et al. 2015). The purchase of frozen, pre-cooked, ready-to-eat meats has increased rapidly because of an innovative food service industry, which continuously introduces new products to meet the growing consumer demand for quick foodservice (Younathan et al., 1980). Products that offered a greater degree of convenience than basic and complex ingredients, like RTC (ready-to-cook) and RTE (ready-to-eat) meals and snacks, constituted 26 percent of the average household food budget between 1999 and 2010 (Okrent and Kumcu, 2016). Ground beef can be classified as a food staple because it is consumed at least once weekly, and ground beef is the leading protein for weekday dinners (McCarty and Neuman, 2013). In ground beef, the beef lean-to-fat ratio typically ranges from 50% lean and 50% fat up to 97% lean and 3% fat. In 2005, approximately 42% of beef was consumed as ground beef (Davis and Lin, 2005). In addition, the U.S. Department of Agriculture purchases of ground beef for NSLP (National School Lunch Program) are a small share of the value of all ground beef sold in the United States, some $50 million annually. Yet, these sales are an important component of certain ground-beef plants' business: the mean NSLP supplier sold about 11% of its ground beef to NSLP (Ollinger and Bonvay, 2017).

Fourteen percent of linear foot space in self-service retail meat cases was devoted to ground beef in 2010, up from 12% in 2008 (National Meat Case Study, 2010). In 2012, there were 34.1 million head of cattle slaughtered of which, 26.7 million were steers and heifers and the remaining 6.8 million head were cull beef, dairy (cows and bulls) and some of the animals being imported to the United States (ERS, 2012). Consumer consumption of this beef amounted to about 26.4 billion pounds, or 0.08 kg/person/day. About 60% of the 26.4 billion pounds of meat, or 16 billion pounds, was consumed as hamburger patties (National Cattleman's Beef Association, 2012). This drastic increase in ground beef consumption was a result of poor economic situations, which caused many consumers to modify their selection from higher priced steaks and roasts to lower cost items, such as ground beef (McCarty, 2011).

In producing ground beef, the meat industry can choose among several methods for reducing the particle size of beef trimmings before the final grinding operation. Chopping of raw materials in a food hopper or silent cutter has been used to produce chopped beef that is then packaged in keeper casings for distribution to other processors and retailers for final grinding (Berry, 1980). Particle size reduction in the production of ground beef patties can be achieved by grinding, flaking, chopping, chunking or slicing and has been shown to affect ground beef palatability (Lin and Keeton, 1994). Processing methods have been related to tenderness, juiciness, and overall acceptability of ground beef (Cross et al., 1980). Berry and Chen (1976) reported that the inclusion of CO_2 pellets during chopping extended shelf-life and reduced off-flavor. Randall and Larmond (1977) found that flaked-cut beef patties have total cooking losses that were similar to those of patties made from ground beef

Source of Meat

The primary source of lean ground beef is not from feedlot finished cattle, but from mature cows and bulls, as well as from imported lean beef trimmings (Pruitt and Anderson, 2012). In the United States, supplies of mature cows and bulls are limited compared to feedlot finished cattle, as an average of 5.9 million cows and bulls have been slaughtered under federal inspection annually compared to 26.2 million steers and heifers. Meat from young, finished dairy-type cattle is typically darker than meat from young beef-type cattle and even though Charolais-sired cattle are more muscular, Holstein-sired cattle have more marbling and darker colored lean (Pfuhl et al., 2007). When analyzing individual raw materials used in the ground beef formulation, Mendenhall (1989) showed that bull meat had more variable pH and myoglobin content than either the two-piece chuck or the beef trim of steers. Mendenhall (1989) warned that blending bull meat (pH >6.0) with other meats to lower the pH value (<5.7) of ground beef might not be desirable, because the pigments in all of the individual particles in the mixture would not denature at the same rate. Carcass pH of forage-fed cattle tends to be higher than that of grain-fed cattle (Watanabe et al., 1993). Vestergaard et al. (2000) concluded that muscle from forage-fed bulls was darker and contained more pigment compared with meat from concentrate-fed bulls. Cow beef had a higher pH and a darker lean color than young beef (Graafhuis and Devine, 1994). Beef products derived from culled cows is generally considered lower quality due to color and tenderness; therefore, a greater proportion of cow beef is typically used to produce ground beef (Raines et al., 2009).

Ground Beef Color

Consumers associate meat color with freshness and use color as a major criterion in selecting meat products (Kropf, 1993). Consumers generally associate a bright red color with freshness and wholesomeness (Jenkins and Harrington, 1991), and find products less desirable as color darkens. The type of myoglobin and amount and pH can alter the color of the muscle. The state of myoglobin, more specifically the iron moiety, may influence the appearance of cooked product. Heating with iron in a reduced state (ferrous) produces a pink pigment, ferrohemochrome or globin myohemochromogen. Alternatively, heating with iron in the oxidized (ferric) state results in the formation of a brown pigment, ferrihemochrome or globin myohemichromogen (Wong, 1989; Lawrie, 1991).

Monitoring the internal color of ground beef patties for the degree of doneness is commonly used by many food preparers and consumers (Warren *et al.*, 1996). When assessing color in a laboratory or research setting, instrumental color of lightness, redness, and yellowness

(L^*, a^*, b^* respectively) of the surface/interior of patties are measured multiple times. Once these values have been recorded, it is possible to calculate hue angle ($HA= \tan^{-1} (b^*/a^*)$; represents an angular position between the true red axis and the true yellow axis) and chroma ($C^*= \sqrt{(a^{*2}+b^{*2})}$; C^*: represents the total color or vividness of color). Alternatively, heating with iron in the oxidized (ferric) state results in the formation of a brown pigment, ferrihemochrome or globin myohemichromogen (Wong, 1989; Lawrie, 1991). When consumers use low fat patties, a considerable pink color may be evident at any of the minimum internal temperatures thresholds and holding times regulated by the USDA (Mendenhall, 1989). Clarity of juices is not only difficult to evaluate, it can be used only when the product is at the heat source. Once the product has been removed from the heat source, the consumer cannot rely on color as an indicator of thorough cooking (Van Laack et al. 1996b). Van Lack *et al.* (1996), concluded that the precooking conditions as well as the final internal cooked temperature influence the color of cooked beef patty color. They also found that after the cooking, the storage process seemed to affect the color of cooked product.

Cooking Method

Meat is a complex food with a highly structured nutritional composition. It becomes safer to eat and more digestible when it is subjected to cooking (Rodriguez-Estada et al., 1997). The method of cooking determines the meat's composition, particle size and sensory attributes especially appearance, color and juiciness of the meat product (Mohammad et al., 2010). However, heat treatment can lead to undesirable modifications, especially the loss of nutritional value. Three main factors differ among cooking techniques: the temperature on the surface of the meat, the temperature profile through the meat, and the method of heat transfer (Danowska-Oziewicsz, 2009). The National Livestock and Meat Board defines internal temperature endpoints for beef as: very rare (55°C); rare (60°C); medium rare (65°C); medium (70°C); well-done (75°C) and very well done (80°C) (Brewer and Novakofski, 1999). Cooking the product from 81 to 85°C resulted in lower a* values, C*, 630/580 nm ratio, and greater hue angles, but had no effect on L* and b* values (Berry and Bigner-George, 1999).

Cooking method and temperature are important factors that affect ground beef patties (Campbell et al., 1977). Berry and Leedy (1984) evaluated the effects of fat content and cooking method (electric broiling, charbroiling, roasting, convention heating, frying, and microwave cooking) and found that microwave cooking reduced yield when compared with other cooking methods, regardless of fat level in the raw product. Yet, microwave cooking has several advantages, including rapid heating, ease of control and lower energy usage (Choi et al., 2008; Kirchner et al., 2000; Jeong et al.,2004); however, there are many disadvantages to cooking in microwave ovens, including non-uniformity of heating, edge overheating, soggy texture, and lack of browning. Jeong et al. (2004), also observed that moisture content of higher fat beef patties decreased when charbroiled, fried, and microwaved. Dreeling et al. (2000) cooked beef patties from frozen state to an internal temperature of 72°C, and, although cooking method did not affect the fat or protein content of cooked burgers, the deep-fat frying method produced the lowest moisture content when compared to broiling, browning, conventional oven roasting or microwave. Cooking method was shown to influence sensory and instrumental textural assessment of low-fat beef burgers (Dreeling et al., 2000). Among six cooking methods for beef patties, conventional roasting produced the highest initial tenderness ratings, with char-broiling and broiling being intermediate, and frying and microwave cooking being the lowest (Berry and Leedy, 1984). Mohammed et al. (2010) found that the moisture, fat retention, and cooking yield were better in the microwave oven cooked products; however, sensory panelists graded hot-air oven cooked patties with higher scores than other cooking methods. Beef patties cooked from the fresh and frozen state on electric griddles frequently have the opposite internal color distribution, with pink/red color in the outer edge and brown color appearing in the center (Berry, 1991). This is due to the outer edge raising up from heating surface, leaving the center of the patty more in contact with the griddle surface.

In the food service sector, one of the biggest customers is schools for their lunch programs. Many of the elementary and secondary schools in the United States have included beef patties that have been precooked, frozen, and are reheated for serving (Berry et al., 1981). Precooking of meat is a simple procedure that, if properly performed, will permit assurances made to consumers that meat is virtually free of viable pathogenic microorganisms. Precooking is perceived as a more “consumer friendly” approach than irradiation. Additionally, precooking provides convenience to consumers in products not normally marketed as consumer foods (Katsanidis and Addis, 1999). Even though this is a method of providing quick meals for school staff, students and faculty there are some downsides to this type of preparation. Bowers and Engler (1975) found that the precooked and reheated patties had less meaty aroma and flavor, as well as having higher frequencies of “metallic,” “sweet,” and “rancid” flavors.

Persistent Pinkness

Persistent pinking is a defect in cooked beef characterized by an abnormal pink appearance in fully-cooked product, which is undesirable because the consumers anticipate a dull-brown color (Suman et al., 2016). Ground beef patties that contain deoxymyoglobin in their interior have myoglobin (Mb) that denatures and color that develops in an expected manner when cooked, which results in a slightly pink appearance at a medium degree of doneness, 71°C (Warren *et al.* 1996). Patties cooked to 71°C from the thawed state tend to appear browner than patties cooked from the frozen state to 71°C (Van Laack et al., 1996b). High pH beef (pH > 6.0) is also "hard-to-cook," exhibiting a persistent red, undercooked appearance even when cooked to internal temperatures adequate for browning normal beef cuts (Mendenhall, 1989). High pH values may result from long-term stress to animals prior to slaughter. Red to pink color in fresh cooked meat has been attributed to several factors, including, nitric oxide (Brant, 1984), stress (Babji et al., 1982), differing concentrations of myoglobin (Froning et al., 1968), and the formation of a reduced nicotinamine-denatured globin hemochrome during cooking (Cornforth el al., 1986). When myoglobin is denatured, hemochromes are formed. Under reducing conditions, pink globin hemochromes may develop, in turkey (Cornforth et al., 1986) and pork (Howe et al., 1982; Ghorpade and Cornforth, 1993). Van Laack et al. (1996b) observed that the occurrence of red color in beef patties cooked to 71°C was associated with incomplete denaturation of myoglobin at higher pH values. Even at the higher end of endpoint cooking temperatures, some of the myoglobin is not heat denatured. Berry and Bigner (2000) found that fat content does not appear to influence the presence of pink/red color when fresh patties are cooked, but less pink/red color was found for thawed patties from high-fat ground beef compared to low-fat ground beef. Warming patties in steam tables or in vacuum pouches, where patties may be submerged in juices, has been reported to be another source for the formation of pink, denatured globin hemochromes (Cornforth, 1996). Berry and Bigner (1999) found that cooking patties, predisposed to pink color at 71°C, to higher internal temperatures to eliminate the pink color, may not be as detrimental to sensory and tenderness properties as generally believed. Several studies (Kregal et al. 1986; Troutt et al. 1992) have compared the effects of cooking to 77° vs 71°C and observed that the higher internal temperature substantially reduced juiciness ratings, but other sensory properties were not greatly affected. Schmidt and Trout (1984) reported that high pH inhibited the formation of a brown cooked meat color. Mendenhall (1989) found that the lack of brown cooked color was most visible in meat with the highest concentrations of myoglobin. Several conditions other than undercooking may result in pink or red color in cooked meat (Van Laack et al, 1996b). High pH and high pigment concentration are associated with limited myoglobin denaturation (Mendenhall, 1989; Trout, 1989). Contamination with nitrite or nitrate (Froning et al., 1967), ammonia (Shaw et al., 1992), and exposure to CO or NO gases (Froning, 1983) leads to formations of compounds, such as nitrosomyoglobin, that have a red color. Nitrogen dioxide may be present as fuel-combustion byproducts in gas-fired ovens leading to the formation of a pink ring (Cornforth et al., 1998). The occurrence of pink color seems to be more frequent when muscle pH is high (>6.0) and greater concentrations of total muscle pigments are present (Mendenhall, 1989). When the raw product contains more metmyoglobin (MMb), the cooked product will appear more done than when the product contains more oxymyoglobin (OMb) (Van Laack et al., 1996b). Consumers complain when cooked 71°C ground beef patties, which are normally grey inside, retain a red, pink raw color after cooking (3 to 4 min). Additional cooking (1 to 3 min) will remove the red, pink color but not without a concurrent loss of quality, particularly texture and juiciness (Mendenhall, 1989).

Berry and Bigner (1999) evaluated the properties of beef patties cooked to elevated internal temperatures as a means of reducing persistent pink color. For their treatments, all the formulation A was manufactured from a combination of 90% lean boneless cow beef and 60% lean boneless beef navels; B was processed using U.S Select boneless beef chucks; and C was made from boneless beef trimmings from U.S. Utility and select forequarters. Formulation A received the lowest firmness score and possessed less breakdown in chewing than formulation C. Formulation A was processed with more cow beef than the other two formulations, and formulations that contain more cow beef have reduced cooked tenderness. They also found that cooking to 81 to 85°C resulted in lower a* values, C*, and 630/582 nm ratios, as well as greater HA, but did not influence L* and b*values. The major results from their study showed that processors need to closely monitor the effects of variation in raw materials have on properties of cooked beef color. Beef patties produced from more mature cow muscle display more pink/red cooked color properties than patties manufactured from young cow beef (Berry, 1998). Refrigerated thawing of beef patties for approximately 24 hours produces less pink and more brown color following cooking compared to cooking patties from the frozen state (Van Laack et al., 1996a; Lavelle et al., 1995; Berry and Bigner, 1999).

Lean Finely Textured Beef vs Finely Textured Beef

Lean finely textured beef (LFTB) has been used since the early 1980s (Rabobank, 2012). However, LFTB became a more recognized product after the product sold by Beef Products Incorporated (BPI) was at the center of media and consumer publicity in March 2012 (Andrews, 2012). The process of extracting LFTB recovers approximately 45.4 kg more lean beef from each carcass. That LFTB from meat and fat excluded from other cuts results in a diverse and profitable product (Moon et al., 2016). Cross (2012) and Rabobank (2012) argued that the inability to use LFTB resulted in the need for an additional 1 to 1.5 million head of cattle to be slaughtered annually. With the shortage of beef cattle around the country, beef companies have found that LFTB utilizes more of each carcass which results in an increase in available product (Neilson, 2016). The overall value of a beef carcass has been increased due to production of LFTB, which has allowed consumers to experience near constant prices of products like hamburgers (Pruitt and Anderson, 2012). The cost savings from the use of lean finely textured beef is ground beef mixtures may not be large but helps to explain why an estimated 75% of hamburger patties sold in the United States contained lean finely textured beef by mid-2008.

The manufacturing process for LFTB involves the grinding of high-fat beef trimmings, subsequent heating to around 38°C and centrifugal force is used to separate the lean. The final step in the LFTB manufacturing process is to rapidly freeze and cut the LFTB into pieces for shipping. The LFTB process allowed lean beef to be taken out of trimmings that contain a high percentage of fat. The extracted LFTB, approaching 100% lean beef, can be blended with other beef to increase the percentage of lean which consumers continue to demand (Pruitt, 2012). Lean finely textured beef never accounts for more than 15% of a ground beef mixture comprised of lean trimming that range from 94 to 97% chemical lean (Pruitt and Anderson, 2012). Moon et al. (2016) found that the inclusion of LFTB up to 20% could lend many positive quality characteristics to both fresh and cooked ground beef patties. When comparing LFTB manufacturing to FTB manufacturing, the processes are similar, however the main difference is the additives after the product has been made. Beef Products Incorporated (BPI) exposes the LFTB to ammonium gas to produce ammonium hydroxide which acts as an antimicrobial while ultimately raising the pH. Cargill Meat Solutions product, finely textured beef is exposed to citric acid which serves a similar role in killing foodborne microbes but lowers the pH of the final product (Carr et al., 2012).

Ground Beef Patties with Lean Finely Textured Beef

There is limited information concerning the effects of LFTB on the quality characteristics of meat products, even though LFTB has been widely used in the meat industry for over 20 years. As LFTB inclusion increased from 0, 25, 50, or 75%; pH, lightness, and redness increased in raw ground beef (Van Laack et al., 1997). Internal color of cooked ground beef patties was redder as the proportion of LFTB increased in the ground beef formulation. Addition of LFTB did not affect the palatability attributes of fermented beef sausages (Smith et al., 1991).Consumer palatability ratings improved when 15 to 25% LFTB was added to ground beef formulated to a lean composition of 80 and 90% (Maddock and Spronk, 2004). Neilson (2016) found that consumers showed a preference for a maximum inclusion (15% of formulation) of finely textured beef for tenderness but numerically the differences were minor. This is a positive for the beef industry, as consumers cannot detect a difference in ground beef patties with the inclusion of finely textured beef. Beef patties which contained LFTB resulted in a well-done cooked color despite having a high pH, compared to patties not containing LFTB (Van Laack et al., 1997). In normal patties, Van Laack et al. (1997) found that the inclusion of LFTB resulted in increased a* and C*; however, when included in dark cutting patties, a higher LFTB content was associated with lower a* and C* values. Although HA of normal patties was unaffected by LFTB level, HA of dark-cutting patties increased with increasing proportion LFTB levels.

Conclusion

Due to the increased demand in precooked meals (mainly meat entrée) in today's society as well as consumer demand for higher quality products, there is a need to solve the problems that occur in the precooked hamburger market. With the relatively low cost of the product and its quick ability to be prepared by the consumer, much work is needed to make this precooked product meet the high standards of the consumer both in household and commercial use. The major concern facing this market now is persistent pinkness where the product retains a pink, undercooked color when it has been cooked to an endpoint temperature where it should have a brown, well done color. The cause of the persistent pinkness has been well studied, but it is still a commonly occurring issue in the market. This is a cause for concern when looking at the meat that goes into ground beef production. The majority of the meat that is used for ground beef comes from culled bulls and cows which often have meat with higher pH values than young steers and heifers. Utilizing finely textured beef (FTB) to lower the pH of the patty blend, as well as enhance the sensory characteristics, has not been studied in-depth. Not only does this lower the pH of the formulation, but also adds a more concentrated source of lean to the blend. Patty formulations, storage procedures, and cookery methods seem to be the way of alleviating this common problem. Because ground beef patties represent the world's most popular processed meat, the solution to this common problem becomes paramount. There is still much work that needs to be conducted in finding ways to use the formulation of the patty blend, as well as the cooking process, to try and alleviate this looming problem. Therefore, the objective of this study was to characterize the effects of bull:cow blend proportions, with or without finely textured beef (FTB), on internal cooked color of precooked ground beef patties.

Chapter II: Effect of 50:50 Proportion of Bull:Cow Blend Levels and Incorporation of Finely Textured Beef on the Color of Precooked Ground Beef Patties

Abstract

Variation in internal cooked color of ground beef is an economic concern for the ground beef market. Persistent pink color in hamburger patties can lead consumers to the perception of an undercooked product. Therefore, the objective of this study was to characterize the effects of bull:cow blend proportions, with or without finely textured beef (FTB), and cookery method on internal color of precooked ground beef patties. Batches (9.1 kg) of 85% lean ground beef were manufactured with 0, 33, 67, or 100% 50:50 bull:cow blend (remainder of lean was 100, 67, 33, or 0% Select-grade knuckles, respectively) mixed with 2 kg of 50:50 lean:fat trim and either 0 or 15% FTB, resulting in 8 treatment formulations with 5 replicates. Batches were mixed in a commercial mixer-grinder for 5 min before being ground through a 0.95-cm plate, and formed into 150-g patties (40/batch). Fresh color (L*, a*, and b*) was measured after patties were formed (n=6/ treatment batch). Patties were cooked in an impingement oven to internal temperature of 71°C, submerged in an ice bath before measuring internal cooked color (n=6). The next day, frozen cooked patties were reheated to an internal endpoint temperature of 71°C on a char-grill (CHAR), clam-shell griddle (PAN), or forced-air convection oven (OVEN) before measuring internal reheated color. Data were analyzed as a slit-plot design, with the whole plot treatments in a 4 × 2 factorial arrangement with PROC GLIMMIX of SAS. Fresh patties became darker, less red, and more yellow (linear, $P \leq 0.012$) with increasing proportions of bull:cow blend, whereas FTB addition increased ($P < 0.05$) L* values and decreased ($P < 0.05$) a* and b* values of fresh patties. Cooked patties became darker (linear, $P < 0.001$) with increasing bull:cow blend, and addition of FTB reduced ($P < 0.05$) internal a* and b*. Reheated L* values

decreased with increasing bull:cow blend (linear, $P < 0.001$), and inclusion of FTB reduced ($P < 0.05$) a* values in reheated patties. Patties reheated in OVEN were lighter ($P<0.05$), more red ($P < 0.05$), and yellow ($P < 0.05$) than patties reheated in PAN or on CHAR.

Introduction

Ground beef comprises between 50 and 60% of the beef consumed in the United States (Laird et al., 2019). Ground beef can be classified as a food staple because it is consumed at least once weekly, and ground beef is the leading protein for weekday dinners (McCarty and Neuman, 2013). Ground beef is one of the most affordable beef products sold in the United States and represents the largest volume of beef sold in the food service industry (64%) and represent more than 37% of revenue sales for both food service and retail industries, respectively (Speer et al. 2015). The primary source of lean ground beef is from culled mature cows and bulls, and, to a lesser extent, from imported lean beef trimmings (Pruitt and Anderson, 2012). Beef products derived from culled cows is generally considered lower quality due to color and tenderness; therefore, a greater proportion of cow beef is typically used to produce ground beef (Raines et al., 2009).

Consumers associate meat color with freshness and use color as a major criterion in selecting meat products (Kropf, 1993). Consumers generally associate a bright red color with freshness and wholesomeness (Jenkins and Harrington, 1991), and find products less desirable as color darkens. However, once the product has been removed from the heat source, the consumer typically associates a redder cooked color with a greater risk of evoking an *E. coli* infection (Olsen et al., 2014). Monitoring the internal color of ground beef patties for the degree of doneness is commonly used by many food preparers and consumers (Warren *et al.,* 1996). The method of cooking determines the meat’s composition, and sensory attributes especially appearance, color and juiciness of the meat product (Mohammad et al., 2010). Precooking of meat is a simple procedure that, if properly performed, will permit assurances made to consumers that meat is virtually free of viable pathogenic microorganisms, and provides convenience to consumers (Katsanidis and Addis, 1999). Van Laack et al. (1996a) concluded that the precooking conditions as well as the final internal cooked temperature influence the color of cooked beef patty color.

Persistent pinking is a defect in cooked beef characterized by an abnormal pink appearance in fully-cooked product, which is undesirable because the consumers anticipate a dull-brown color (Suman et al., 2016). High pH beef (pH > 6.0) is also “hard-to-cook”, exhibiting a persistent red, undercooked appearance even when cooked to internal temperatures adequate for browning normal beef cuts (Mendenhall, 1989). There has been some work in the addition of finely-textured beef to ground beef to help with the alleviation of persistent pinkness. The process of extracting LFTB allows around 45.4 kg more lean beef to be recovered from each carcass, from meat and fat excluded from other cuts into a diverse and profitable product (Moon et al., 2016). The extracted LFTB, approaching 100% lean beef, can be blended with other beef to increase the percentage of lean which consumers continue to demand (Pruitt, 2012). Lean finely textured beef never accounts for more than 15% of a ground beef mixture comprised of lean trimming that range from 94 to 97% chemical lean (Pruitt and Anderson, 2012). When comparing LFTB manufacturing to FTB manufacturing, the processes are similar; however, the main difference is the additives after the product has been made. Beef Products Incorporated (BPI) exposes the LFTB to ammonium gas to produce ammonium hydroxide which acts as an antimicrobial while ultimately raising the pH. Cargill Meat Solutions product, FTB is exposed to citric acid which serves a similar role in killing foodborne microbes but lowers the pH of the final product (Carr et al., 2012). There is limited information concerning the effects of FTB on the quality characteristics of meat products, even though FTB has been widely used in the meat industry for over 20 years. As LFTB inclusion increased from 0, 25, 50, or 75%; pH, lightness, and redness increased in raw ground beef (van Laack et al., 1997). This is a positive for the beef industry, as consumers cannot detect a difference in ground beef patties with the inclusion of finely textured beef. Beef patties which contained LFTB resulted in a well-done cooked color despite having a high pH, compared to patties not containing LFTB (van Laack et al., 1997).

Additional methods of patty formulation, as well as the cooking process are needed to alleviate the persistent pinking problem. Therefore, the objective of this study was to characterize the effects of 50:50 proportion of bull:cow blend levels, incorporation of finely textured beef, and cookery method on the color of precooked ground beef patties

Materials and Methods

Ground Beef Production and Data Collection

For this project, eight treatments were created to test the effects of batch formulation with or without finely-textured beef (FTB; Cargill Protein, Wichita, KS) on the incidence of persistent pinkness during the initial cooking and recooking stages. Mature bull chuck clods (Lone Star Beef Processors, San Angelo, TX) and denuded cow sirloin butts (Caviness Beef Packers, Hereford, TX) as well as A-Maturity, USDA Select-grade peeled knuckles (IMPS#167A; USDA 2014), 50:50 beef trimmings, and finely-textured beef (FTB; Cargill Protein, Wichita, KS) were purchased and shipped to the University of Arkansas Red-Meat Abattoir (Fayetteville, AR) and stored at 2°C for 48 hours before grinding. After denuding, bull clods, cow sirloin butts, Select knuckles and 50:50 lean trimmings were individually coarse ground through a 1.6-cm plate (Hollymatic Countryside, IL). During coarse-grinding, random 100-g “grab” samples were collected, and fat content of each sample were analyzed with a Digital Fat Tester (model HFT 2000; Data support Co., Inc., Encino, CA) before the manufacture of 9.1-kg batches of 85% lean ground beef. The "lean" portion consisted of 0, 33, 67, or 100 % of a 50:50 blend of bull clods and cow sirloin butts with the remainder composed of coarse ground knuckles (100, 67, 33, 0%, respectively), and 2.2 kg of 50:50 beef trimmings were included as the "fat" portion of the ground beef formulations. In addition to the "base" treatment ground beef formulations, 1.36 kg of "lean" was replaced with an equal amount of FTB, resulting in a total of 8 treatments (5 replicated batches for each of the treatment ground beef formulations (Table 1).

After weighing, the batches were blended one at a time in a commercial mixer-grinder (Grinder-Mixer 150; Hollymatic Countryside, IL) for 5 minutes before being ground through a 0.95-cm plate (grinder was disassembled, cleaned, rinsed and dried between each batch). After final grinding, 150-g patties were formed (Model Super Patty Machine; Hollymatic Corp., Countryside, IL). Patties not used for raw color and pH measurements were stored overnight at 2°C in boxes with plastic liners.

Six randomly selected patties from each batch were exposed to air for 30 min at 2°C before measurement of pH and raw instrumental color analysis. Instrumental color was measured with a handheld spectrophotometer (MiniScan EZ 4500L, Hunter Lab, Reston, VA) recording L* (lightness), a* (redness) and b* (yellowness) as well as visible spectrum reflectance (400 to 700 nm), using illuminant A and a 2.54-cm aperture. The spectrophotometer was calibrated before data collection with a standard white and black tiles, then again after every 500 readings. Three readings were recorded on the outside of each patty and were averaged together for L*, a*, b* values. Hue angle (HA) and chroma (C*) were calculated from the a* and b* values of each patty as: $\tan^{-1}(b^*/a^*)$ and $[a^{*2}+b^{*2}]^{[1/2]}$, respectively (AMSA, 2012). Additionally, the reflectance data were used to calculate the proportions of deoxymyoglobin (%DMb= {1.395 – $[\frac{(A572-A700)}{(A525-A700)}]\}x100$), metmyoglobin (%MMb=$\left\{2.375\ x\ \left[1-\frac{A473-A700}{A525-A700}\right]\right\}x\ 100$), and oxymyoglobin (%OMb=100-[%DMb+%MMB]), where A473, A525, A572 and A700 are the natural log of the reflectance values at 473, 525, 572 and 700 nm, respectively (AMSA, 2012). The pH was analyzed after standardizing the pH meter (model AP25, Denver Instrument Co., Arvada. CO, USA) before each day to pH standard solutions with pH values of 4.0, 7.0, and 10.0 respectively. The pH of 3 of the patties was obtained by placing the probe inside the patty via the edge and left until the pH held constant and the patties were placed back with the rest of the patties that had been set aside. After the spectrophotometry and pH analysis were completed, 3 of the 6 patties were taken for fat analysis to confirm accuracy of formulation to 85% lean. These randomly selected patties from each batch were homogenized in a food processor, and the homogenate was smeared on glass filter paper, covered with another glass filter paper, and then placed into an aluminum tray of the meat fat analyzer (model HFT 2000; Data Support Company, Inc., Panorama City, CA).

Initial Cook Data Collection

Patties (n=40/treatment batch) were cooked on an impingement oven (model 1100; Lincoln Enodis, Fort Wayne, IN, USA) that was set to 218°C with a belt speed of 26.67 cm/min, with a 5-cm gap between patties and were cooked to an internal temperature of 71°C. If patties were not cooked to 71°C once exiting, they were placed back into the oven to complete cooking. Patties (n=6/treatment batch) were selected at random from each batch, placed inside a zip-top bag and subsequently submerged into an ice bath (1°C) to stop the cooking process; the remainder of the patties were placed on racks and frozen at -20°C until frozen for 1 hour before being stacked (5 patties/stack). Once frozen, patties (n=21/treatment batch) stored for reheating the next day and patties (n=12/treatment batch) were vacuum-packaged and stored at -20°C until reheated later during the consumer sensory panel.

After initial cooking, the 6 patties/treatment batch were removed from the ice bath, and external instrumental color (L*, a*, b* values, as well as visual spectral values) were determined using a MiniScan EZ 4500L (Hunter Lab, Reston, VA). After the external patty color was determined, each patty was cut in half (parallel to the cutting board) and 3 internal color readings were determined. In addition, degree of doneness was visually appraised according to the 5-point scale (1 = red/rare to 5 = gray or brown/well done); Marksberry et al. (1993).

Reheated Data Collection

Frozen cooked patties (n=21/treatment batch) were reheated to an endpoint internal temperature of 71°C using 1 of 3 methods (n=7/treatment batch for each method): 1) placed on wire racks and reheated in a preheated (176°C) forced air convention oven (OVEN; Zephaire E model; Blodgett Oven Co., Burlington, VA, USA), 2) in a clam-shell style Panini grill set at 6 (PAN; model CG14; Star Manufacturing International, Inc., Smithville, TN, USA), or 3) on a gas-fired, open hearth char-broiler set at medium-high heat (CHAR; model 6148RCBD; Star Manufacturing International, Inc., Smithville, TN, USA). Patties reheated via OVEN method were checked after 7 minutes, and internal patty temperature was monitored with a hand-held thermometer (MK28; Comark Instruments, Inc., Beaverton, OR). Patties reheated via PAN method were checked after 7 minutes, and internal patty temperature was monitored with a hand-held thermometer. Patties reheated on the CHAR were turned every 2 minutes, and internal patty temperature was monitored with a hand-held thermometer, and, after all patties achieved the desired internal endpoint temperature, reheated patties were placed in zip-top freezer bags and submerged into a 1°C ice-water bath to stop the cooking process.

After reheating, 6 patties from each treatment batch were removed from the ice bath, and external instrumental color (L*, a*, b* values, as well as visual spectral values) were determined using a MiniScan EZ 4500L (Hunter Lab, Reston, VA). After the external patty color was determined, each patty was cut in half (parallel to the cutting board) and 3 internal color readings were determined. In addition, degree of doneness was visually appraised according to the 5-point scale (1 = red/rare to 5 = gray or brown/well done); (Marksberry et al., 1993).

Consumer Taste Panel

Patties from 6 treatment formulations (0,33, and 67% bull/cow blend, with and without FTB) were used for consumer sensory evaluation at the University of Arkansas' Food Science Department (Fayetteville, AR). Frozen, pre-cooked patties were reheated to an internal endpoint temperature of 71°C in preheated (medium setting) clamshell griddles (George Foreman model GRP4842P; Spectrum Brands, Inc., Beachwood, OH). Immediately after reheating, patties were cut into 6 equal-sized pieces, placed in aluminum foil, and held at 63°C in food warmers (model MP-941, Henny Penny, Eaton, OH) until served to consumers (n=142). The consumers selected from a pool of over 4,000 based on an e-mail questionnaire requesting consumers that ate ground beef 3, or more, times weekly. Consumers were scheduled for 20-minute sessions, with 8 consumers seated in climate-controlled booths with lighting adjusted to conceal visual degree of doneness. Each panelist was served pieces from each of the 6 treatment formulations in a random order, and salt less saltine crackers and water were supplied to all panelists. Consumers were asked to rate each piece for juiciness, beef flavor, texture, and overall likeability using a 9 point hedonic scale (1 = extremely dislike to 9 = extremely like).

Statistical Analysis

Raw and initial cooked patty data were analyzed as a 4 x 2 factorial design, with main effects of proportion of bull:cow blend (BCB) trimmings in the formulation (0, 33, 67, 100%) and finely-textured beef (0 vs. 15%). In addition, reheated patty data were analyzed as a split-plot design, with BCB x FTB combinations as the whole-plot effects and reheating method (OVEN x CHAR x PAN) as the subplot effect, with batch within BCB x FTB and batch within BCB x FTB x reheating method as random effects used to test whole – and subplot effects, respectively. Since all precooked patties were reheated in clam-shell style griddles for consumer sensory panels, reheated sensory data were analyzed as a 3 x 2 factorial design, with panelist within session included in the model as the random effect. There were 5 replicates (batches) of each ground beef formulation and reheating method, and the analysis of variance was generated with the general linear mixed models (GLIMMIX) procedure of SAS (SAS Inst., Inc., Cary, NC, USA). Least square means were calculated for all main and interactive effects, and separated statistically with pairwise *t*-test (PDIFF option of SAS) when the *F*-test was significant ($P \leq 0.05$). Moreover, linear and quadratic contrasts were used to discern the effect of the proportion of BCB on color of raw, cooked and reheated ground beef patties.

Penalty analysis was conducted on the consumer sensory data. Data were collected on a 9-point hedonic scale, then collapsed to show JAR (Just about right) rating on a 3-point scale: 1 = too weak, 2 = just about right, 3 = to strong. Average liking among the 3 categories (Juiciness, Texture, and Flavor) were taken and mean-drop analysis was conducted for the attributes that were at least 20% or more “Not-JAR”. Total penalty numbers were the result of the mean drop multiplied by the percentages Not JAR. (AMSA, 2015).

Results

Fresh Patty Results

Fresh patties became darker, less red, and more yellow (linear, $P \leq 0.012$) with increasing proportion of bull/cow blend (Table 2). Also, with the increased inclusion of bull/cow blend in the patty formulation, the reflectance values of the patties showed a decrease, (linear, $P < 0.05$) from 600 nm to 700 nm (Figure 1). Chroma (C*) values decreased ($P < 0.001$) across blend and FTB percentage in the blend. Fresh patties also showed that the 15% inclusion of FTB patties had greater ($P < 0.05$) reflectance values from 400 nm to 600 nm than the 0% FTB patties, then the 0% inclusion of FTB patties had greater ($P < 0.05$) reflectance values from 630 nm to 700 nm (Figure 2). Finely textured beef addition decreased ($P \leq 0.05$) L*, a* and b* values of fresh patties (Table 3). There were no differences in pH ($P > 0.05$) between the varying levels of bull/cow trim or the inclusion of FTB in the patty blend.

Cooked Patty Results

Internal color of cooked patties became darker (L*, linear, $P \leq 0.001$) with increased inclusion of bull/cow blend (Figure 3) and addition of FTB reduced ($P \leq 0.001$) internal cooked redness (a*; Figure 4) and yellowness (b*; Figure 5) of patties. There were no differences found between the internal or external a* values of the cooked patties in relation to the varying levels of bull/cow blend. When analyzing the external L* and b* values, there was a decrease (linear, $P < 0.05$) with the increased inclusion of bull/cow blend (Table 4); however, there was no blend x FTB interaction that was detected. With the increased inclusion of bull:cow blend, we saw no effect on visual color score ($P = 0.962$) of the patties after initial cooking.

Reheated Patty Results

Reheated patties internal L* values decreased with the increased inclusion of bull/cow blend percentages (linear, $P < 0.001$, Figure 6), and the inclusion of FTB reduced ($P < 0.05$) internal a* values in reheated patties (Figure 7). Increased inclusion of bull:cow blend percentages also reduced (linear, $P < 0.05$) external L*, and b* values of the patties. There was a blend x reheating method effect for internal L* ($P = 0.021$) where increased inclusion of bull:cow trim decreased L* values in CHAR and PAN L* values when compared to OVEN patties. Internal L* and a *of reheated patties decreased (linear, $P < 0.05$) between OVEN, and the other methods (Figures 8, 9). Reheated internal b* values where greatest in the CHAR patties and lowest in the OVEN ($P < 0.05$, Figure 10). The external values of the patties reheated in OVEN were lighter ($P < 0.05$, L*, Figure 11), and more yellow ($P < 0.05$) than patties reheated in PAN or CHAR (Figure 12). The external a* values of the reheated patties were highest in the patties that had been reheated to 71°C in OVEN patties and lowest in the patties that were reheated via the CHAR method (Figure 13). Increased inclusion of FTB in the patty blend formulation resulted in higher MMb% ($P = 0.001$) as well as reheating method where CHAR and PAN had higher amounts MMb% than those patties reheating via the OVEN method.

Consumer Sensory Panel Results

In the consumer sensory panel, there was a decrease (linear, $P < 0.001$) in the juiciness JAR score with increased inclusion of bull:cow blend and increased inclusion of FTB in the patty formulation but there tended ($P < 0.10$) to be a blend x FTB interaction (Table 5). Also, there was a blend x FTB interaction ($P < 0.05$) with a decrease (linear, $P < 0.001$) in the texture JAR score with increased inclusion of bull:cow blend and increased inclusion of FTB in the patty formulation (Table 5). Flavor JAR of the patties tended ($P < 0.10$) to decrease with increased inclusion of bull:cow blend and no effect was seen on the addition of FTB on flavor. There was a blend x FTB interaction on overall likeability, where increased inclusion of bull:cow and FTB decreased ($P = 0.013$) overall likeability.

Discussion

Consistent with the results of the present study, Moon et al. (2016) and Van Laack et al. (1997) reported that fresh patties became lighter (greater L* value) with the increased inclusion of LFTB in the patty formula. In addition, Moon et al. (2016) reported that patties containing 10 and 20% LFTB had reduced b* values (yellowness). Conversely, the present research showed that patties containing FTB had reduced a* values (redness); whereas, Moon et al. (2016) reported that as LFTB inclusion increased in the patty formulation, the fresh patties became more red (increased a* values). In the present study, increased inclusion of FTB in the patty formula HA increased ($P < 0.044$). Chroma (C*) values in the present study were not only affected by the proportion of bull:cow but also the FTB inclusion. Conversely, Moon et al. (2016) reported that LFTB inclusion had no effect on the calculated C*. Differences in pH might account for the color variation, but there were no differences in the measured pH between the varying levels of bull:cow trim or the inclusion of FTB in the patty blend (Figure 14, 15). Hollenbeck et al. (2018) found that with increased inclusion of mature bull trimmings (MBT) in ground beef formulations, fresh patties became darker (decreased L*, $P = 0.005$). This is similar to what was seen in the present study were the increased inclusion of bull:cow proportion reduced L* (lightness) values. Van Laack et al. (1996b) noted that when the raw product contains more metmyoglobin (MMb), the cooked product will appear more done than when the product contains more oxymyoglobin (OMb). In the present study, there was a blend and an FTB effect on the percentage MMb in the raw patties. This higher percentage of MMb in the raw patties with the inclusion of FTB may have led to the reduction of internal a* values for the cooked patties. In the present study, internal a* of cooked patties was reduce with the inclusion of FTB ($P \leq 0.001$). Alternately, Van Laack et al. (1997) found that in normal patties (not dark cutting), the inclusion of LFTB resulted in higher a* values.

Similar to Hollenbeck et al. (2018) who saw no effect on internal a* with increased inclusion of MBT, the present study saw no effect on internal a* values with increased inclusion of bull:cow proportion of the patty formulation. Hunt et al. (1999) found that values for a* and saturation index were highest (increased redness) for patties with OMb, intermediate for patties with DMb, and lowest for MMb. In the current study, there was an increase of calculated %MMb with the increased inclusion of bull/cow blend percentages of the reheated patties. This was also evident in the patties with FTB included in the blend, there was an increase between patties that had either 0 or 15% FTB. This is notable because it has been shown that an increase in % MMb reduces persistent pink color in cooked patties that gives the patties a more well-done appearance when cooked to 71°C.

It has been well documented that cookery method has been known to alter internal cooked color of ground beef patties. Beef patties cooked from the fresh and frozen state on electric griddles frequently have the opposite internal color distribution, with pink/red color in the outer edge and brown color appearing in the center (Berry, 1991), which could have altered the sensory aspect of the patties. Yancey et al. (2011), found that steaks cooked on clam shell style griddles exhibited lower internal a* values than those cooked in forced-air convection ovens or chargrilled. In the present study, there was a reduction in internal a* when comparing clam shell style cookery to forced-air convection but not differences between clam shell and chargrill. Results in the resent study also show that patties cooked via CHAR had the highest HA values; whereas Yancey et al. (2011) showed that clam shell style grills produced the highest HA values. External L* values of patties were also influenced by cookery method. Browning effects from the CHAR and PAN patties where more evident due to direct contact with the heating source.

There is paucity consumer sensory panel data on precooked burgers with the inclusion of finely textured beef. Neilson (2016) looked at cooked 81% lean ground beef patties with varying levels (0, 15, or max inclusion) of FTB. Results for the initial portion of the sensory panel showed no differences were found in juiciness, flavor, or overall likeability between 0% FTB, 15% FTB, and max inclusion FTB pieces. Conversely, the current study showed that there was a blend x FTB interaction ($P = 0.028$) for the texture JAR where the increased inclusion of bull:cow blend and FTB decreased texture of the patties and a tendency ($P < 0.10$) of a blend x FTB interaction for the juiciness JAR to decrease with increased inclusion of bull:cow blend and FTB inclusion. Similarly to Neilson, panelists reported no differences in the flavor of the patties with increased inclusion of FTB. Key differences between Neilson study and this current study is that Neilson's ground beef patties were only cooked once, and the patties in the current study had 4% higher fat content.

Conclusion

The inclusion of FTB reduced redness (a*) in both the fresh patties and internally in the cooked patties but did not influence the internal redness (a*) of the recooked patties. Patty pH was not affected by the addition of FTB (15%). It is possible that the myoglobin in the FTB that could denature quicker resulting in the lower a* values, giving the cooked patties a less red appearance since pH did not differ between treatments. Reheating method influenced the overall cooked appearance of not only the outside, but the inside of the patties as well. Patties cooked via the CHAR and PAN method were both darker and less red than those cooked in the oven. Contrary to previous publications, consumers in our taste panel preferred patties that did not include FTB. The current study and the available literature show that finely textured beef has the ability to improve the color scores that relate to a more well-done appearance, but more work is necessary to assess the consumer's likeability of the patties in order to produce a more consumer friendly product.

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Figures and Tables

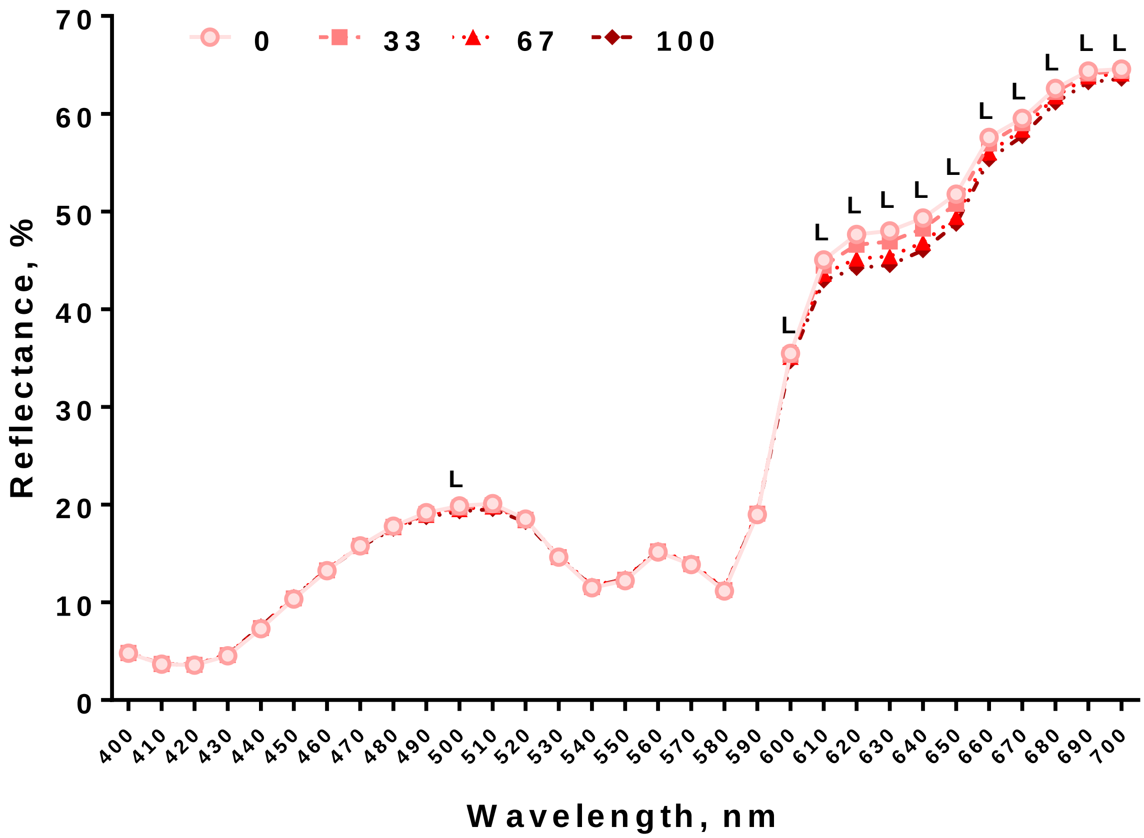

Figure 1.
Effects of bull:cow blend (0, 33, 67, 100%) on reflectance values of raw, fresh beef burger patties. L above datum points at a specific wavelength indicates a linear decrease (*P* < 0.05) with increasing proportions of bull/cow blend.

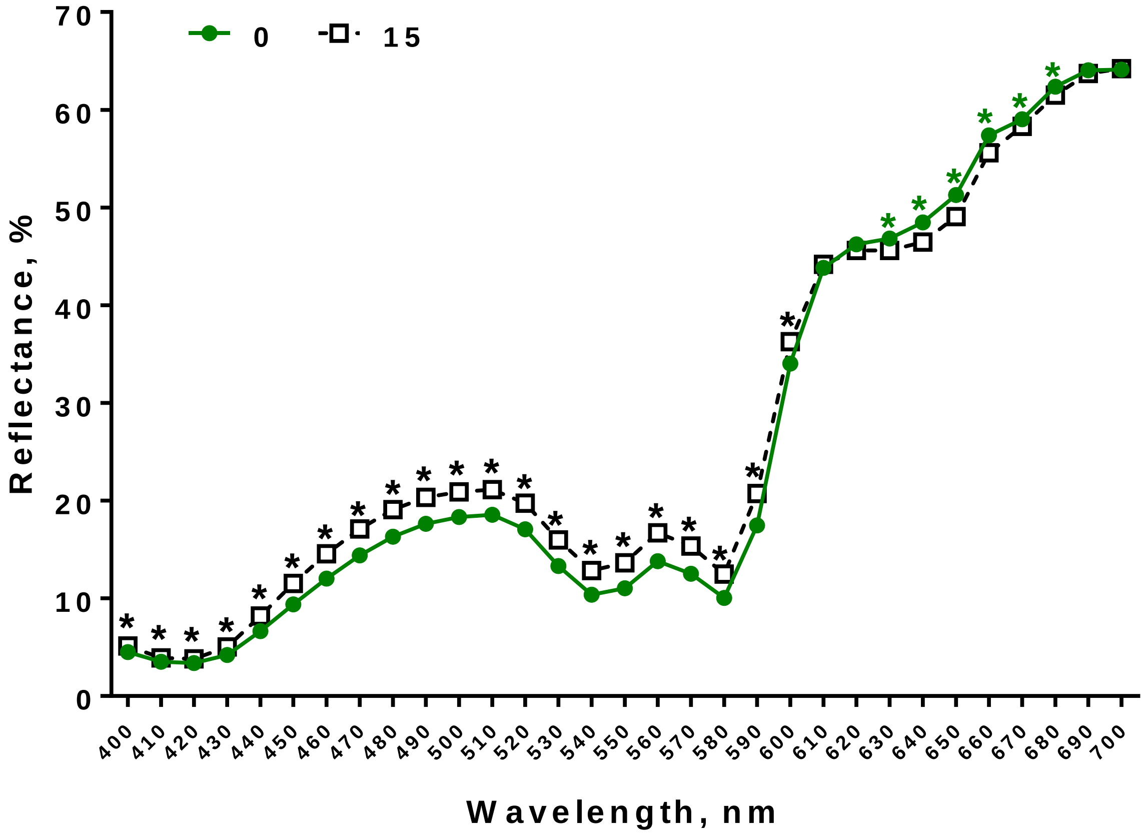

Figure 2.
Effects of finely textured beef incorporation (0, 15%) on reflectance values of raw, fresh beef burger patties. Asterisk (*) indicate at datum points at a specific wavelength indicates that 15 % FTB inclusion was greater ($P < 0.05$) than 0% FTB. Asterisk (*) indicate at datum points at a specific wavelength indicates that 0% FTB was greater ($P < 0.05$) than 15 % FTB inclusion.

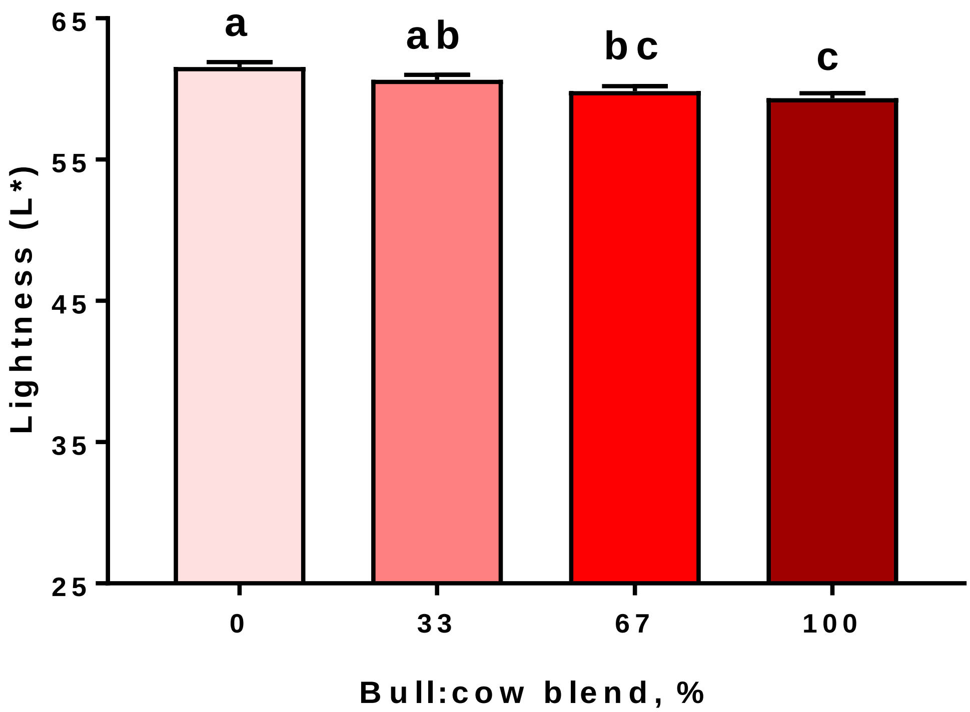

Figure 3.
Effects of bull:cow blend (0, 33, 67, 100%) on internal lightness (L*) values of cooked beef burger patties. [a-c] Within a panel, bars lacking common letters differ ($P < 0.05$).

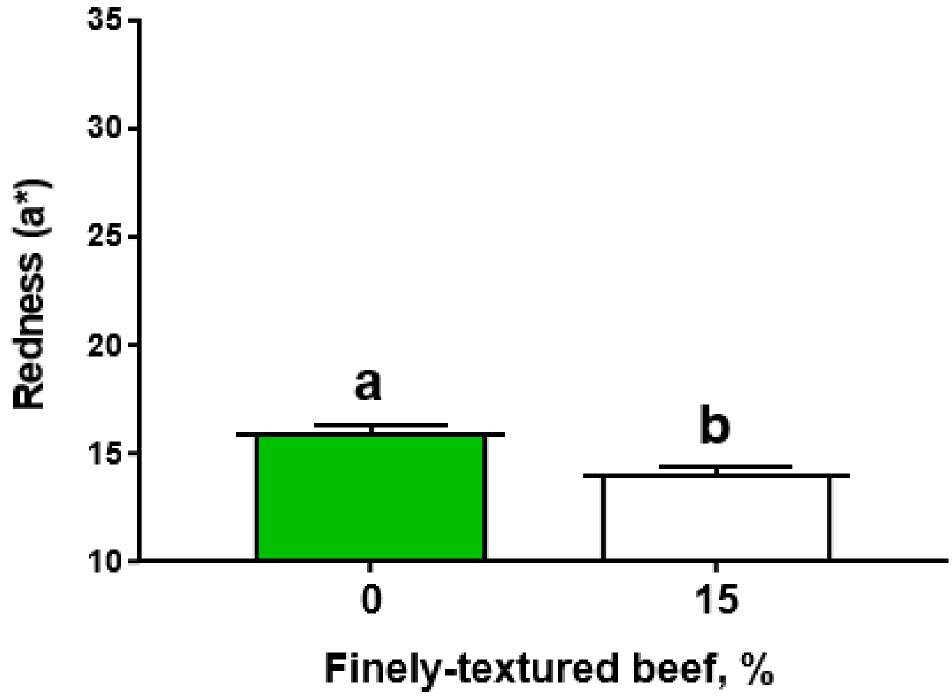

Figure 4.
Effects of finely textured beef incorporation (0, 15%) on internal redness (a*) values of cooked beef burger patties. [a-b] Within a panel, bars lacking common letters differ ($P < 0.05$).

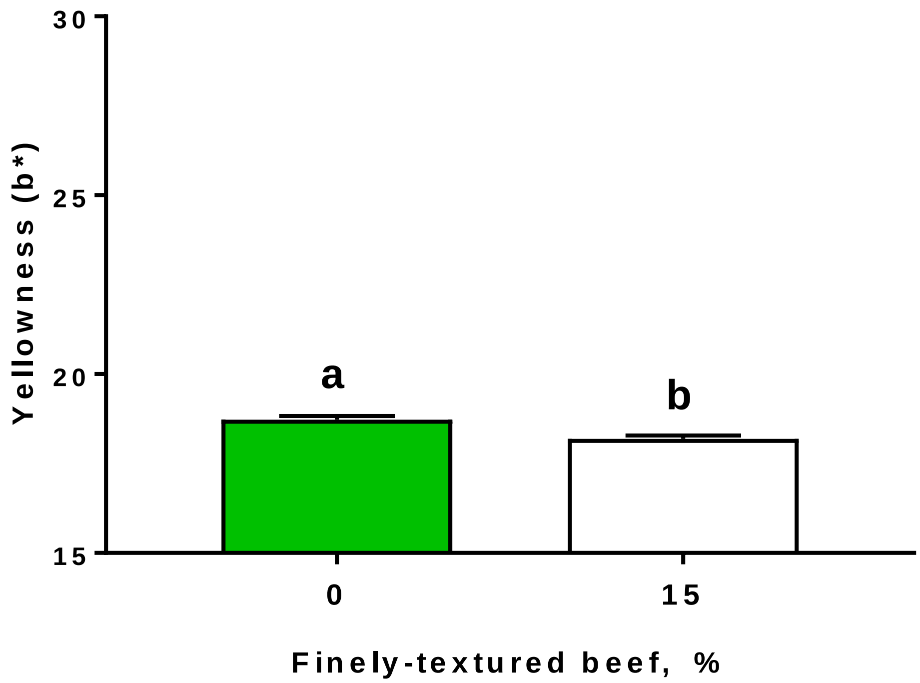

Figure 5.
Effects of finely textured beef incorporation (0, 15%) on internal yellowness (b*) values of cooked beef burger patties. [a-b] within a panel, bars lacking common letters differ ($P < 0.05$).

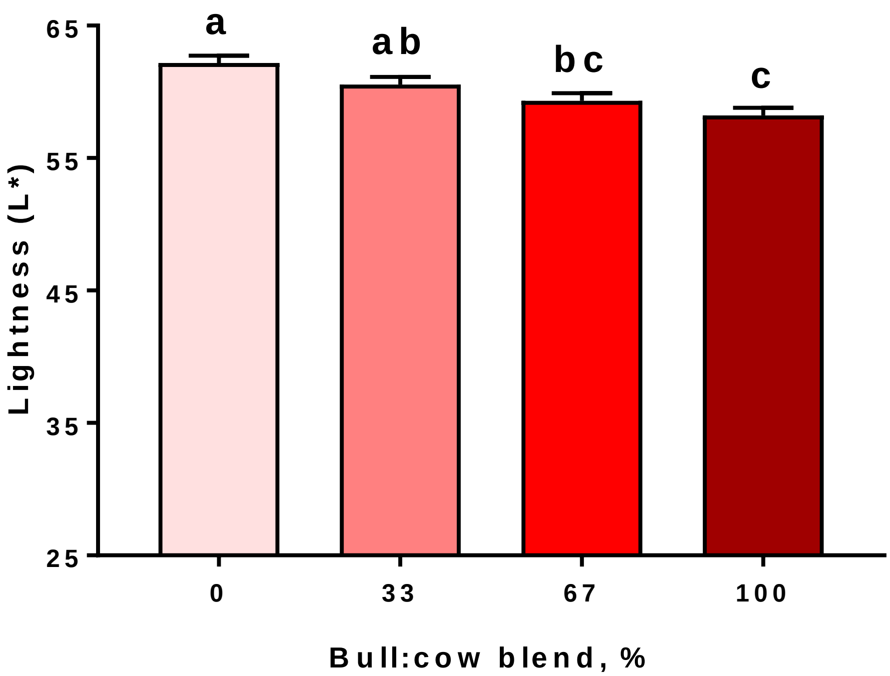

Figure 6.
Effects of bull:cow blend (0, 33, 67, 100%) on internal lightness (L*) values of recooked beef burger patties. [a-c] Within a panel, bars lacking common letters differ ($P < 0.05$).

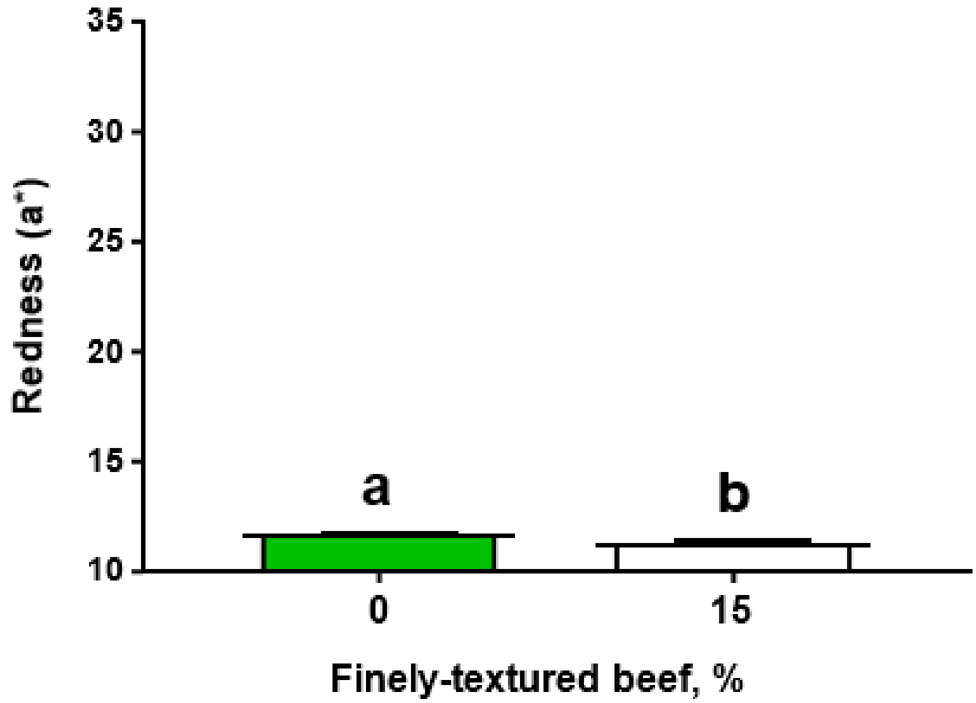

Figure 7.
Effects of finely textured beef incorporation (0, 15%) on internal redness (a*) values of recooked beef burger patties. [a-b] Within a panel, bars lacking common letters differ ($P < 0.05$).

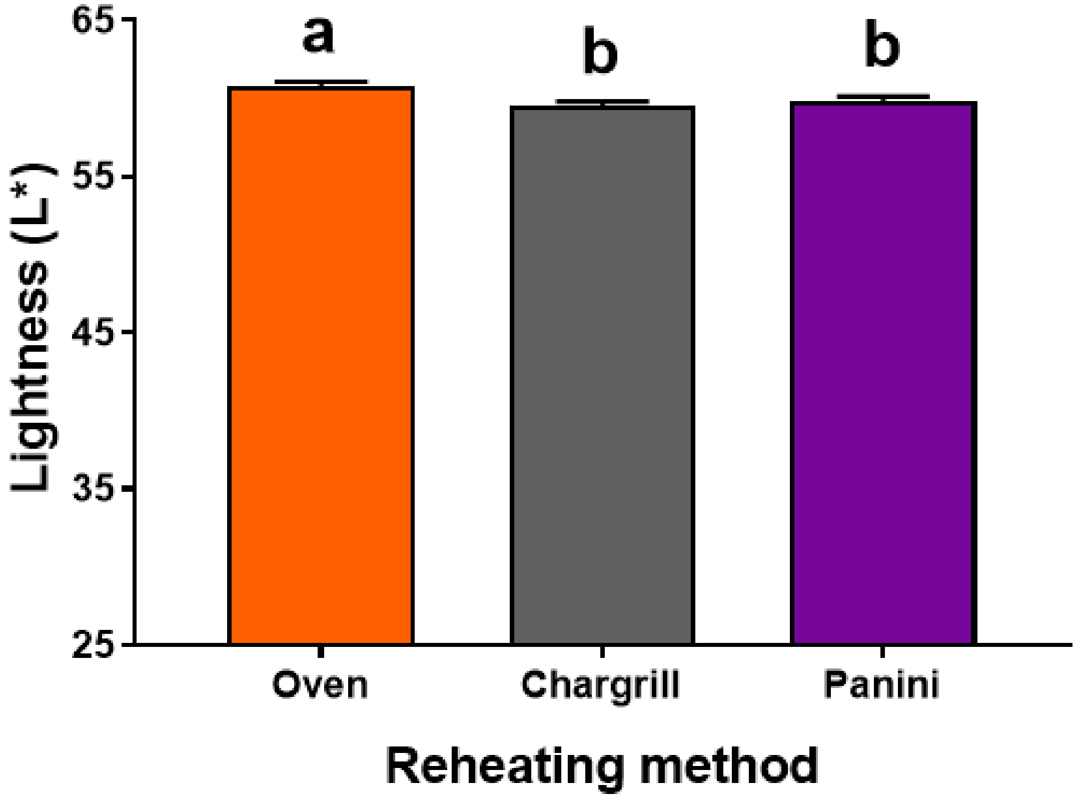

Figure 8.
Effects of reheating method on internal lightness (L*) of recooked beef burger patties. [a-b] Within a panel, bars lacking common letters differ (P < 0.05).

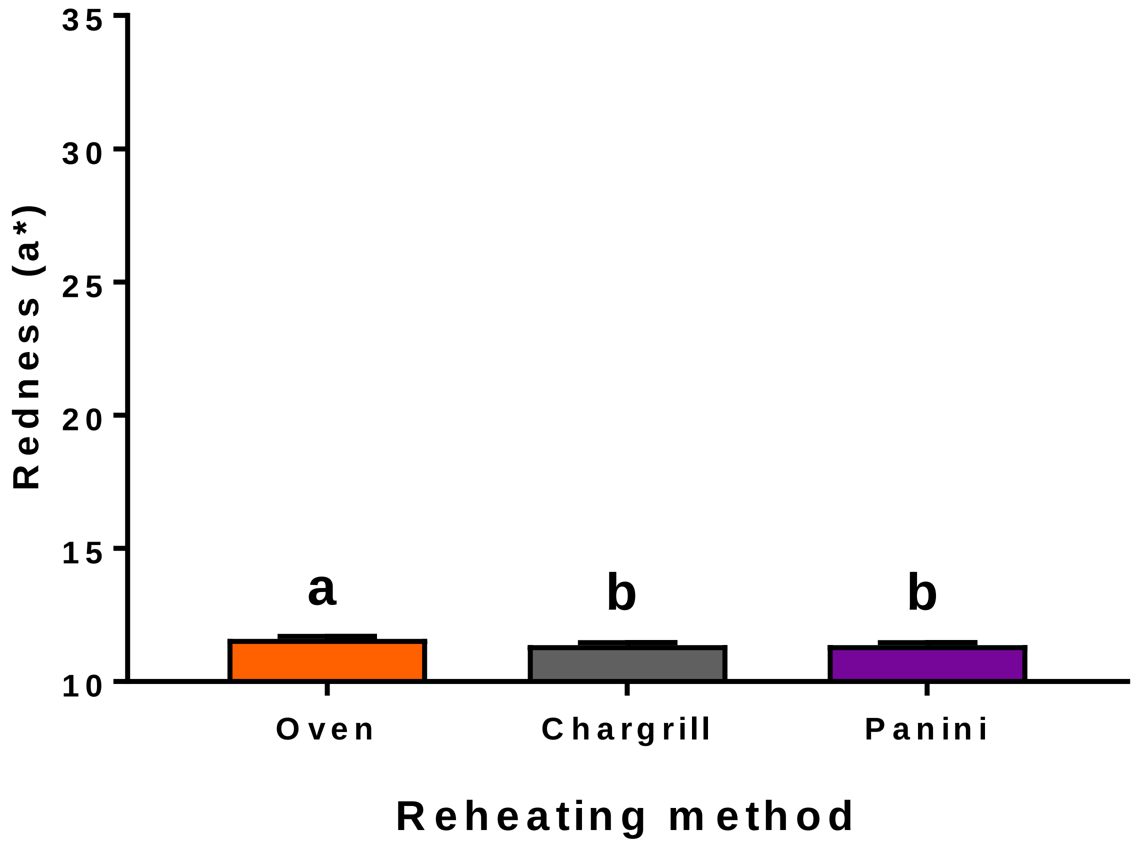

Figure 9.
Effects of reheating method on internal redness (a*) of recooked beef burger patties. [a-b] Within a panel, bars lacking common letters differ ($P < 0.05$).

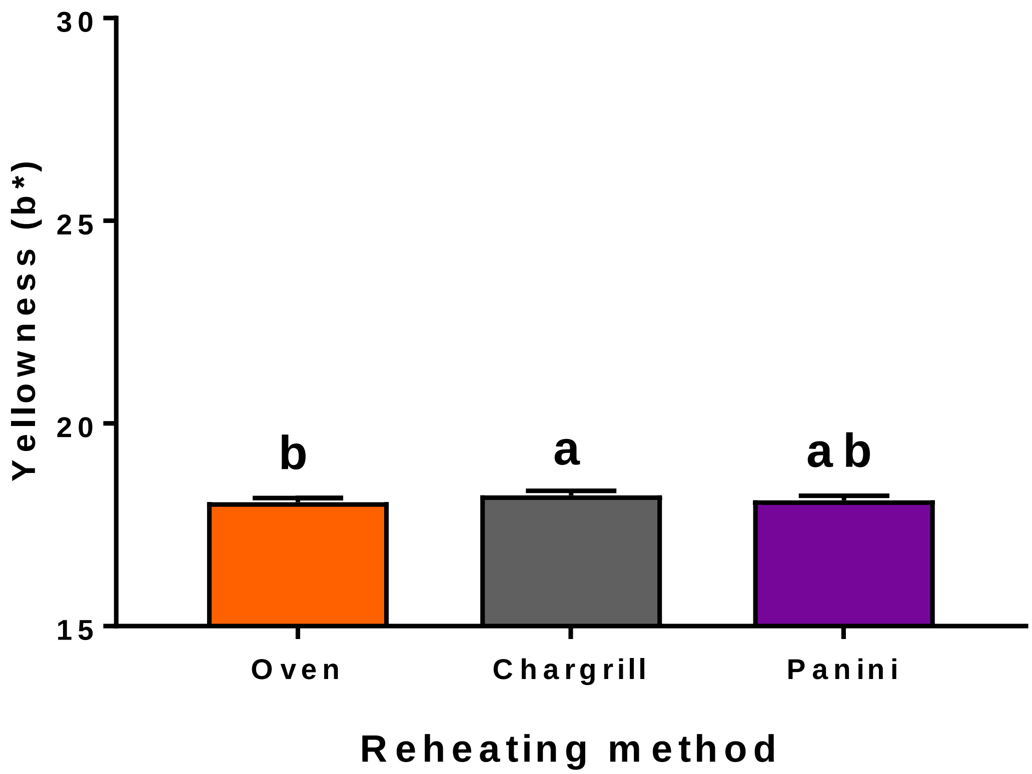

Figure 10.
Effects of reheating method on internal yellowness (b*) of recooked beef burger patties. [a-b] Within a panel, bars lacking common letters differ (*P* < 0.05).

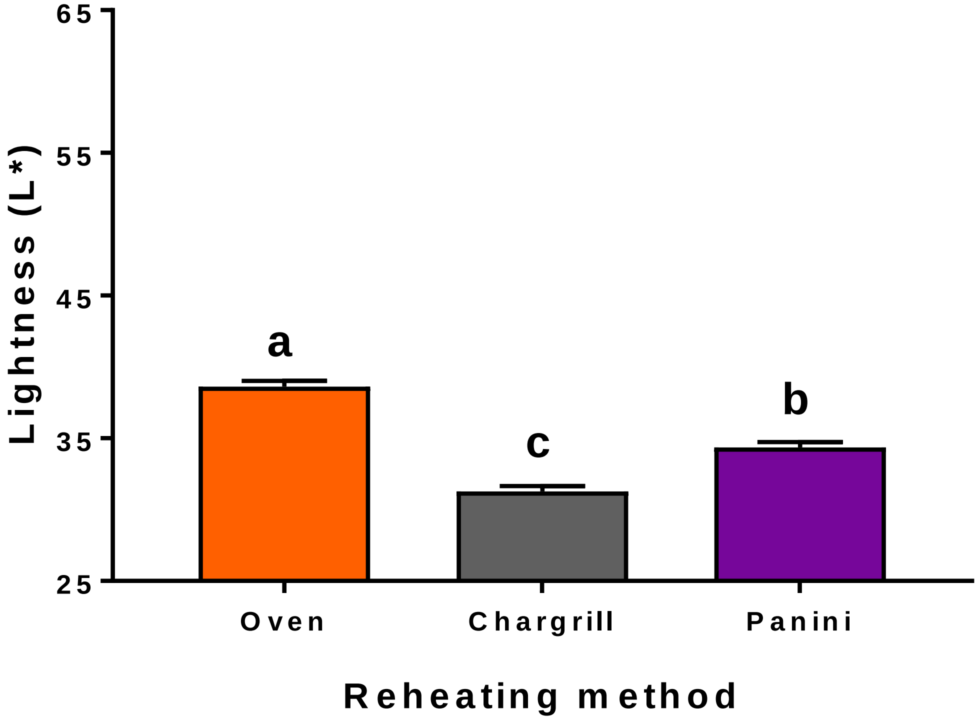

Figure 11.
Effects of reheating method on external lightness (L*) of recooked beef burger patties. [a-c] Within a panel, bars lacking common letters differ ($P < 0.05$).

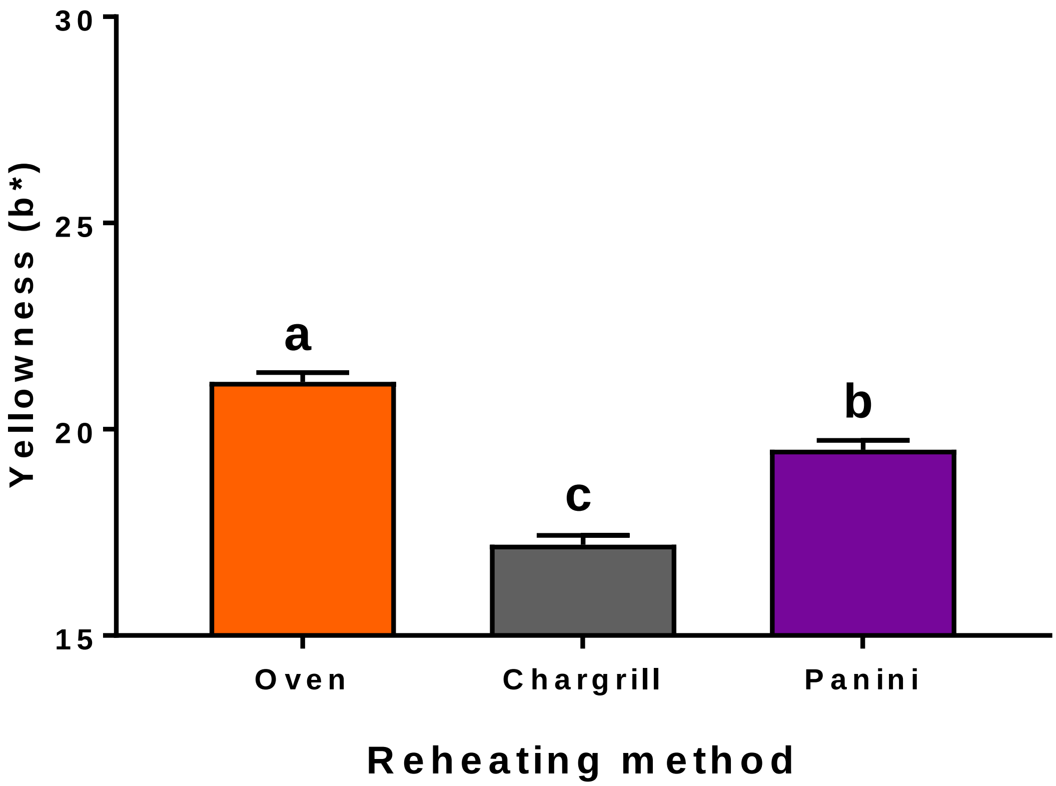

Figure 12.
Effects of reheating method on external yellowness (b*) of recooked beef burger patties. [a-c] Within a panel, bars lacking common letters differ ($P < 0.05$).

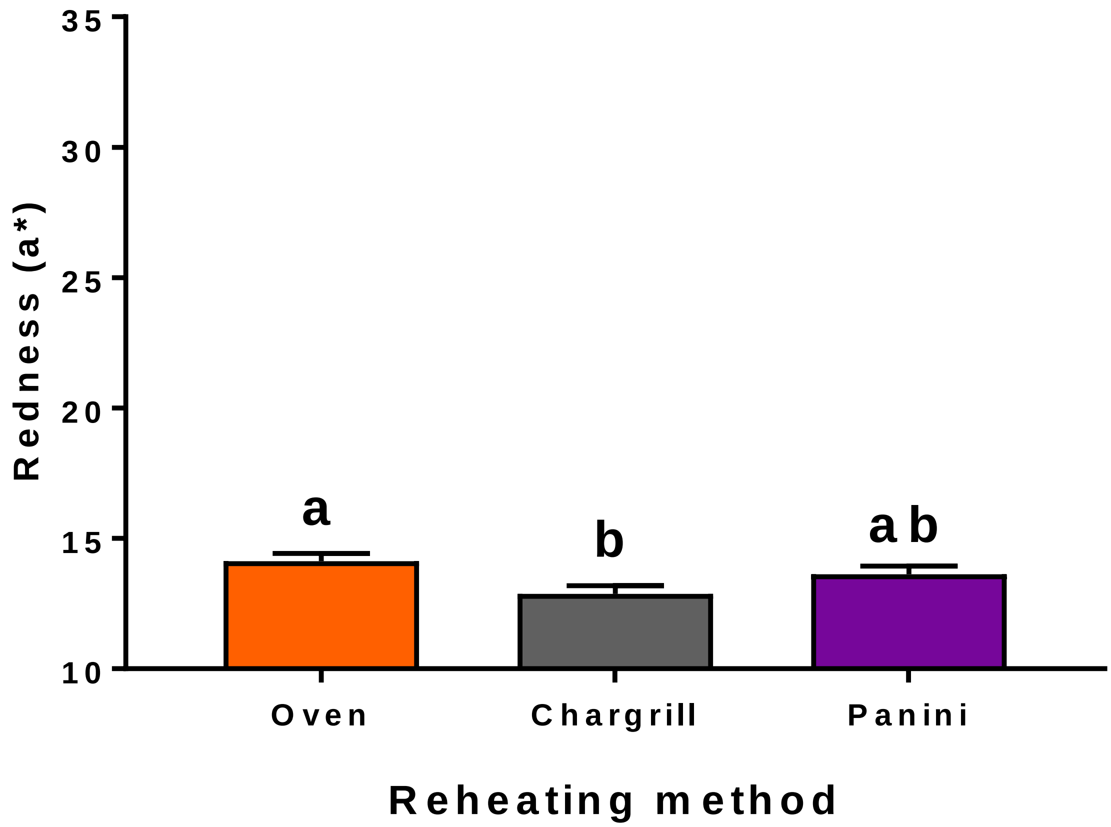

Figure 13.
Effects of reheating method on external redness (a*) of recooked beef burger patties. [a-b] Within a panel, bars lacking common letters differ (P < 0.05).

Table 1. Ground Beef Formulations

		Raw material[1] weights in each batch, kg				
Bull/Cow blend, %	FTB, %	Bull Clods	Cow Butts	50:50 Trim	Knuckles	FTB
0	0	-	-	2.2	6.9	-
0	15	-	-	2.2	5.54	1.36
33	0	1.17	1.17	2.2	4.56	-
33	15	0.89	0.89	2.2	3.76	1.36
67	0	2.28	2.28	2.2	2.34	-
67	15	1.88	1.88	2.2	1.78	1.36
100	0	3.45	3.45	2.2	-	-
100	15	2.77	2.77	2.2	-	1.36

1 FTB = finely-textured beef; Bull clods = mature bull clods; Cow butts = denuded cow sirloin butts; and Knuckles = A-maturity, USDA Select peeled knuckles (IMPS#167A; USDA, 2014)

Table 2. Effects Bull:Cow blend inclusion on color measurements of fresh beef burger patties.

	Bull/Cow Blend, %					*P*-values[a]	
	0	33	67	100	SEM	Blend	Linear
L*	55.59^{X}	55.41^{xy}	55.2^{xy}	54.91^{y}	0.189	0.089	0.012
a*	30.26^{A}	29.73^{AB}	29.00^{BC}	28.76^{C}	0.288	0.003	<0.001
b*	25.15^{A}	24.81^{AB}	24.38^{BC}	24.1^{C}	0.214	0.008	0.001
C*	39.35^{A}	38.76^{AB}	37.89^{BC}	37.62^{C}	0.345	0.004	<0.001
HA	39.8^{y}	39.88^{xy}	40.1^{y}	40.00^{xy}	0.088	0.093	0.044
pH_1	5.41	5.38	5.33	5.34	0.033	0.314	0.102
Fat, %	14.93^{C}	15.61^{B}	16.1^{AB}	16.7^{A}	0.225	<0.001	<0.001
Oxymyoglobin, %	74.60	74.20	73.47	73.60	0.355	0.105	0.025
Metmyoglobin, %	23.3^{B}	23.76^{AB}	24.34^{A}	24.5^{A}	0.294	0.027	0.003
630:580	4.37^{A}	4.24^{A}	4.05^{B}	3.99^{B}	0.065	0.001	<0.001

[a] Probability values for blend and linear effects of the proportion of bull:cow in the ground beef formulation

[A-B] Within a row and main effect, least square means lacking a common superscripted letter differ (P < 0.05).

[X-Y] Within a row and main effect, least square means lacking a common superscripted letter tend to differ (P < 0.10).

Table 3. Effects of finely textured beef inclusion on color measurements of fresh beef burger patties.

	FTB, %			*P*-values[a]	
	0	15	SEM	FTB	BxFTB
L*	54.27[B]	26.28[A]	0.133	<0.001	0.676
a*	31.47[A]	27.41[B]	0.204	<0.001	0.773
b*	25.70[A]	23.52[B]	0.152	<0.001	0.908
C*	40.63[A]	36.18[B]	0.244	<0.001	0.734
HA	39.25[B]	40.64[A]	0.062	<0.001	0.642
pH_1	5.37	5.36	0.024	0.61	0.401
Fat, %	16.34[A]	15.33[B]	0.159	<0.001	0.153
Deoxymyoglobin, %	-2.57[B]	-1.55[A]	0.219	<0.001	0.915
Oxymyoglobin, %	74.2	73.73	0.251	0.199	0.845
Metmyoglobin, %	23.23[B]	24.72[A]	0.208	<0.001	0.946

[a] Probability values for blend and linear effects of the proportion of bull:cow in the ground beef formulation

[A-B] Within a row and main effect, least square means lacking a common superscripted letter differ ($P < 0.05$).

Table 4. Effects Bull:Cow blend inclusion on external color measurements of cooked beef burger patties

	Bull/Cow Blend, %					*P*-values[a]	
	0	33	67	100	SEM	Blend	Linear
L*	45.72[A]	45.19[AB]	43.73[BC]	42.52[C]	0.63	0.004	<0.001
a*	13.97	13.94	13.84	13.52	0.154	0.173	0.045
b*	20.79[A]	20.32[AB]	19.59[B]	19.6[B]	0.317	0.028	0.005
C*	25.06[A]	24.65[AB]	23.99[B]	23.83[B]	0.336	0.047	0.006
HA	56.08[A]	55.5[A]	54.7[B]	55.32[AB]	0.264	0.009	0.014
Color Score	3.20	3.20	3.30	3.20	0.162	0.962	0.964

[a] Probability values for blend and linear effects of the proportion of bull:cow in the ground beef formulation

[A-C] Within a row and main effect, least square means lacking a common superscripted letter differ ($P < 0.05$).

Table 5. Effects Bull:Cow blend and FTB inclusion on consumer sensory data

	Bull/Cow blend, %				FTB, %			*P*-values[a]				
	0	33	67	SEM	0	15	SEM	Blend	Linear	Quad	FTB	BxFTB
Juiciness	6.07^{A}	5.80^{B}	4.64^{C}	0.15	5.86^{A}	5.14^{B}	0.141	<0.001	<0.001	<0.001	<0.001	0.212
Juiciness JAR*	2.50^{A}	2.38^{B}	1.98^{C}	0.063	2.43^{A}	2.14^{B}	0.06	<0.001	<0.001	0.001	<0.001	0.099
Flavor	6.18^{a}	6.08^{a}	5.76^{B}	0.123	6.18^{a}	5.83^{b}	0.114	0.001	<0.001	0.247	<0.001	0.031
Flavor JAR*	2.62	2.60	2.54	0.043	2.61	2.57	0.038	0.221	0.09	0.702	0.367	0.714
Texture	6.32^{a}	6.04^{b}	5.38^{c}	0.135	6.26^{a}	5.57^{b}	0.126	<0.001	<0.001	0.077	<0.001	0.027
Texture JAR*	2.81^{a}	2.77^{a}	2.42^{b}	0.04	2.79^{a}	2.54^{b}	0.036	<0.001	<0.001	<0.001	<0.001	0.028
Overall	6.12^{a}	5.93^{a}	5.21^{b}	0.145	6.13^{a}	5.38^{b}	0.136	<0.001	<0.001	0.011	<0.001	0.013

[a] Probability values for blend, linear, quadratic, FTB and B x FTB effects of the proportion of bull:cow and FTB in the ground beef formulation

[A-B] Within a row and main effect, least square means lacking a common superscripted letter differ ($P < 0.05$).

[*] Penalty analysis was conducted on the consumer sensory data. Data were collected on a 9-point hedonic scale, then collapsed to show JAR (Just about right) rating on a 3-point scale: 1 = too weak, 2 = just about right, 3 = to strong. Average liking among the 3 categories (Juiciness, Texture, and Flavor) were taken and mean-drop analysis was conducted for the attributes that were at least 20% or more “Not-JAR”. Total penalty numbers were the result of the mean drop multiplied by the percentages Not JAR. (AMSA, 2015).